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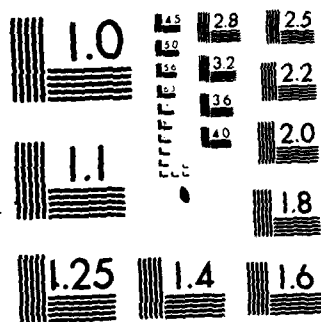
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AN INTEGRATED VIEW ON IMPROVING
COMBAT READINESS

Michael D. Rich, Stephen M. Dresser

February 1982

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Prepared For

The United States Air Force

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A RAND NOTE

AN INTEGRATED VIEW ON IMPROVING
COMBAT READINESS

Michael D. Rich, Stephen M. Drezner

February 1982

N-1797-AF

Prepared For

The United States Air Force



PREFACE

The last few years have seen a marked increase in public expressions of concern about the readiness of our military forces for combat. For the most part, however, the public debate has lacked a consistent and comprehensive framework for articulating issues, assembling facts, pinpointing problems and ascertaining their severity, and evaluating proposed "solutions." This Note contains a set of concepts and illustrations that should contribute to the formulation of such a framework.

The Note summarizes a briefing that was presented initially to the 1981 Defense Science Board Summer Study on Operational Readiness with High Performance Systems. The Note was prepared as part of the Concept Development and Project Formulation Project of the Project AIR FORCE Resource Management Program.

SUMMARY

This Note describes a new approach for identifying and meeting the need to improve combat readiness. That approach rests on three basic ideas. First, readiness can be assessed only within the context of explicit wartime scenarios, a requirement that renders most popular characterizations of readiness (e.g., availability rates) inappropriate and misleading. Second, readiness is the product of many factors, including the weapon system's characteristics, the expected stocks of support resources in wartime, and the performance of support systems. Third, sophisticated equipment is not inconsistent with the goal of high levels of readiness, even in the face of increasingly demanding and stressful combat environments. Achieving that goal, however, will require new, effective support policies, and will require major changes in the customary subsystem and full-system acquisition processes.

ACKNOWLEDGMENTS

The research referred to in this Note was performed by many of our colleagues over the last five years: I. K. Cohen stands out as the principal intellectual force behind many of the concepts discussed. Hy Shulman deserves credit for the ideas about the development and support of combat avionics. Other prominent contributors include Mort Berman, Donald Emerson, Jean Gebman, Richard Hillestad, Thomas Lippiatt, Robert Perry, and Giles Smith. Willis Ware reviewed an early draft and offered numerous constructive suggestions. Responsibility for any errors in fact or interpretation rests with the authors.

CONTENTS

PREFACE	iii
SUMMARY	v
ACKNOWLEDGMENTS	vii
FIGURES	xi
Section	
I. INTRODUCTION	1
Concept of Combat Readiness	1
Measures of Readiness	3
Implications of this View	6
II. IMPROVING THE READINESS OF OUR FIELDIED FORCES	7
Decentralizing Base-Level Maintenance: Combat-Oriented Maintenance Organization (COMO)	8
Increased Interdependency Among Bases in a Theater: A Responsive Intratheater Logistics Transportation System	10
More Effective Use of Limited Test Equipment Resources: The Case of the F-15 Avionics Intermediate Shop	13
Creating "Lean and Mean" Operating Locations: Centralized Intermediate Logistics Concept (CILC)	14
III. ENSURING READINESS OF FUTURE WEAPON SYSTEMS	19
IV. SUMMARY	28

FIGURES

1. Concept of combat readiness	2
2. Some future scenarios and their resulting requirements for Tactical Air Forces	8
3. COMO compared with the standard maintenance structure	9
4. COMO's effect on aircraft launch and recovery measures	11
5. Combat value of a responsive intratheater transportation system: The case of the F-15 F100 engine	12
6. CILC compared with the standard support structure	15
7. Performance after loss of a base: CILC vs. standard structure	17
8. Avionics procurement costs for test equipment and spare LRUs ..	20
9. Removals from Plane 7133 (F-15)	22
10. Removals from Plane 7109 (F-15)	23
11. Comparison of inertial system developments	24
12. Testing and production schedules of five recent tactical aircraft programs	26

I. INTRODUCTION

The charter of the 1981 Defense Science Board Summer Study on Operational Readiness with High Performance Systems centered on the need for improved readiness of combat equipment, a goal that is often translated into the need for more reliable equipment. Improved reliability is obviously important, but combat readiness is affected by several interactive elements--including the manner in which we maintain and support the equipment. This Note presents a view of readiness that integrates both the performance of the hardware and the characteristics and capabilities of support systems.

The work described in this Note is taken from several recent Rand studies, some of which are still in progress. For consistency, most of the chosen topics involve the Tactical Air Forces; however, many of the concepts presented here have been applied to other settings.

CONCEPT OF COMBAT READINESS

There is no widely accepted definition of readiness, and no definition is proposed here. We propose instead a distinctive concept that is helpful in describing readiness, assessing it, and ultimately evaluating alternative policies aimed at improving it. The cornerstone of that concept is the notion that readiness can be characterized meaningfully only in the context of a specific wartime scenario or set of specific wartime scenarios. In other words, a question like, "How ready is the 1st Tactical Fighter Wing?" is meaningless by itself. It is much more meaningful to ask, "How ready is the 1st Tactical Fighter

Wing for a specified, explicit set of wartime scenarios?" Those scenarios need to be fairly detailed because the capability of a particular collection of forces to operate successfully in wartime depends upon a multitude of factors, including those listed in Fig. 1.

We believe that the plausible scenarios of the future will include some that are much more demanding--in many respects--than those that have influenced most defense resource planning and management in the past. The details and implications of this view are discussed below.

- **Readiness refers to**
Projected capability to meet the initial and sustained combat requirements of one or more specific wartime scenarios
- **Characteristics of a wartime scenario include**
 - Identification of unit(s)
 - Initial condition of unit(s) (across all resources)
 - Warning time to deployment
 - Time to initial engagement
 - Expected condition of receiving base(s)
 - Lift requirements and availability
 - Sortie requirements
 - Threat and expected attrition (air and ground)
 - Timing and volume of resupply

Fig. 1 -- Concept of combat readiness

MEASURES OF READINESS

Most of the commonly used measures of readiness are inappropriate or even misleading. One popular measure is the operationally ready (OR) rate--or availability (A_0) rate--observed in peacetime. An indication of the dubious value of such a measure is its widespread use by people arguing both that we are dangerously "unready" and that we are achieving very high states of readiness during normal peacetime operations. Aggregate availability rates observed during peacetime training missions--while useful for estimating peacetime flying needs--are not sufficient for estimating capability in a wartime setting, in which the purpose, frequency, and pattern of aircraft sorties, the amount of available support resources, and the operational environment will be markedly different. Wartime operations differ from peacetime in much more than intensity or scale.

Other measures frequently heard in discussions about readiness consist of a single element drawn from the many that in combination determine readiness. For example, many people tend to equate hardware reliability with readiness, neglecting the importance of varying operational demands, the number and location of spare parts, and the capability of the support system to maintain and repair aircraft and thus, ultimately, to generate sorties. Some people unduly emphasize fill rates, which measure peacetime spare parts "shortages," or utilization rates, which measure the "efficiency" with which support system resources are employed in peacetime. These and similar measures are flawed because they apply to isolated elements of the "readiness" system instead of measuring performance of the system as a whole.

Aware of the limits of peacetime training missions for projecting combat readiness, some observers put their faith in performance measures derived from special surge exercises. Because such exercises often involve the deployment of combat and support resources overseas, they are sometimes alleged to give a fairly accurate picture of our current capability to deploy and operate in the event of a war. Unfortunately, because the setting and conduct of such exercises differ so sharply from the expected nature of many wartime situations, such experiences cannot directly and generally predict wartime performance, though they may be excellent training tools.[1] Models are more promising for that purpose. Early modeling efforts, however, still envisioned wartime as simply a more intensive, scaled-up version of peacetime. The modeling approach was headed in the right direction, but ignored the organizational, operational, situational, and environmental changes that accompany the start of a conflict.

To remedy those deficiencies, a realistic readiness assessment system that military planners can use with confidence must have several characteristics. It must project capability in explicit wartime settings, not merely describe levels of performance achieved in peacetime. It must incorporate not only the commonly measured characteristics of the weapon system, such as its component reliability, but also the quantity and location of important support resources and the characteristics and performance of each important component of the

[1] Such exercises have the potential for providing useful information for wartime readiness projections. However, several problems must be overcome, including sample-size limitations and the lack of a means for measuring the condition of combat-critical subsystems during the exercise.

support system. For particular wartime scenarios, it must be able to evaluate the readiness not only of individual units (or bases) but of more aggregate levels. For example, readiness assessment at the theater level would capture important wartime base differences and interactions. The system must be detailed enough to identify the causes of shortfalls and problems--e.g., insufficient stocks, inadequate numbers of skilled personnel--as well as the relative contribution of each cause to those problems.

It is not surprising that the defense community has relied on less sophisticated indicators, lacking the analytic tools to do better. Recent advances in modeling capability, however, now permit the development of the type of readiness assessment system just described.[2]

[2] These advances have been made and applied by several agencies and organizations, including Rand and the Air Force. One example, known as the Theater Simulation of Airbase Resources (TSAR), is a large simulation model of dozens of sortie generation activities, both within a base and across a theater of bases. By simulating both the activities necessary for generating combat sorties as well as the effects of attacks on our airbases, the model is able to ascertain the effects of the damage and disruption of those attacks on the sortie generation capability of a theater of bases. For more information on TSAR, see Donald Emerson, *An Introduction to the TSAR Simulation Program: Model Features and Logic*, The Rand Corporation, R-2584-AF, February 1982.

Another such model is Dyna-METRIC, an analytic model of the stockage and component repair processes. This model can be used to assess the readiness of a unit or set of units, given resource levels and component repair performance levels. It can derive resource requirements and performance standards from a targeted level of desired capability and also permits the diagnosis of reasons for observed shortfalls. See, for example, Richard J. Hillestad, *Dyna-METRIC: A Mathematical Model for Capability Assessment and Supply Requirements When Demand, Repair, and Resupply are Nonstationary*, The Rand Corporation, R-2785-AF (forthcoming).

The important point is that each of these families of models relates various input measures associated with elements of the so-called readiness system and translates those inputs into projections of war-fighting capability in the context of specific scenarios. For now, war-fighting capability is expressed by measures relating to sortie generation potential, including the number of available aircraft. Measures of combat effectiveness (such as tanks destroyed or bombers intercepted) are preferred but still beyond our reach.

IMPLICATIONS OF THIS VIEW

Our concept of readiness has several implications. The first is that simple characterizations of readiness that lack specific wartime contexts are likely to be meaningless. Moreover, because readiness within such a context is the product of a system of factors, each element of the system is a potential target for improvement. These improvement efforts must be coordinated because changes in one system element affect the others. Assessing the capability of an interactive system of factors--for a set of detailed wartime scenarios--is obviously not an easy task; it requires the use of highly capable models, as well as relevant historical performance data for each system element.

Most important, our work has shown that high states of readiness need not be beyond the reach of very sophisticated or complex weapon systems, although new development strategies and improved support systems are probably necessary to achieve those levels. The remainder of this Note illustrates (1) how changes in support policies and organizations can improve the flexibility, mobility, survivability, and sortie generation of our fielded forces, and (2) how changes in the process by which we develop weapon systems can help assure that we attain high states of readiness with future systems.

II. IMPROVING THE READINESS OF OUR FIELDDED FORCES

This section illustrates ways to improve the combat readiness of forces already in the field. In this Note, however, we are not advocating or endorsing any particular policy described. Instead, we are drawing on several Rand studies that have evaluated various changes in support posture, to demonstrate how such changes can profoundly improve the combat readiness of our fieldded forces.

We have chosen a number of measures--or criteria--for evaluating improvements in readiness, based on several assumptions about the most demanding dimensions of future conflicts in which the Tactical Air Forces may have to operate. Future conflicts might involve one or more of the following: very short warning periods, deployments over long distances into areas lacking highly developed support infrastructures, very large and diverse target sets, the likelihood of attacks on friendly airbases, and rapidly changing operating environments in which the demands and stresses on our forces change dramatically each day (see Fig. 2). Forces operating in such conflicts will require flexibility, mobility, high sortie rates, and sustainability.

Several illustrations follow of how changes in support policies, procedures, and organizations can result in increased sortie-production capability, enhanced flexibility and survivability, and other attributes of improved warfighting capability. The first describes a reorganization of maintenance functions within a base, while the other three concern multibase (or theater) operations.

- Short warning period
- Long distance deployment
- Large and diverse target sets
- Vulnerable infrastructure;
austere environments
- Dynamic conflicts

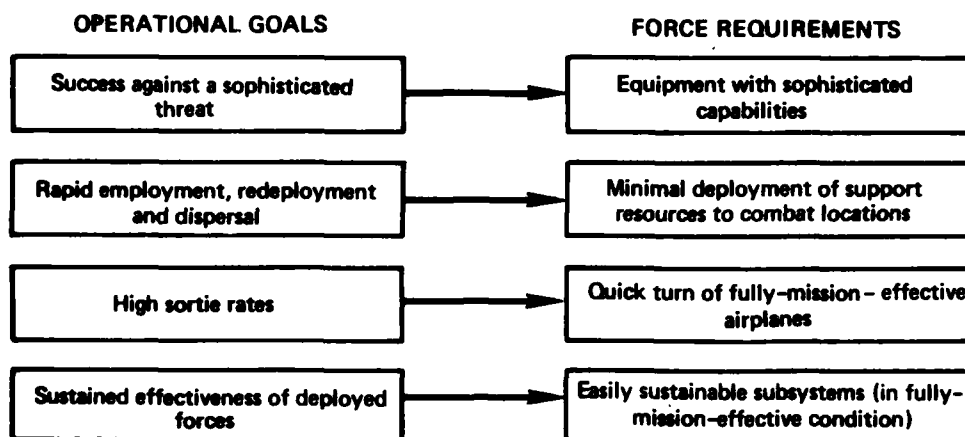


Fig. 2 – Some future scenarios and their resulting requirements for Tactical Air Forces

DECENTRALIZING BASE-LEVEL MAINTENANCE: COMBAT-ORIENTED MAINTENANCE ORGANIZATION (COMO)

The first illustration is the Combat-Oriented Maintenance Organization, or COMO. One way to describe the COMO concept is to compare it with the standard maintenance organization structure, still in use in the Strategic Air Command (SAC) and the Military Airlift Command (MAC) (see Fig. 3). In that structure, aircraft that have completed their missions are examined initially on the flight line by maintenance personnel with general diagnostic capabilities. Those so-called flight-line generalists diagnose problems and relay their diagnoses to a centralized job control center, which in turn dispatches

appropriate maintenance specialists to the flight-line from the back shops located elsewhere on the base. This procedure is efficient when there is not a premium on rapid aircraft turnaround; hence its use in SAC and MAC. When very rapid turnaround time is important, however, as in the case of the Tactical Air Forces during wartime, any alternative that emphasizes flight-line performance and minimizes dispatch time would pay attractive dividends. COMO is such a concept, in which generalist and specialist flight-line maintenance personnel are assigned to squadrons, and the back shops focus exclusively on intermediate level maintenance.

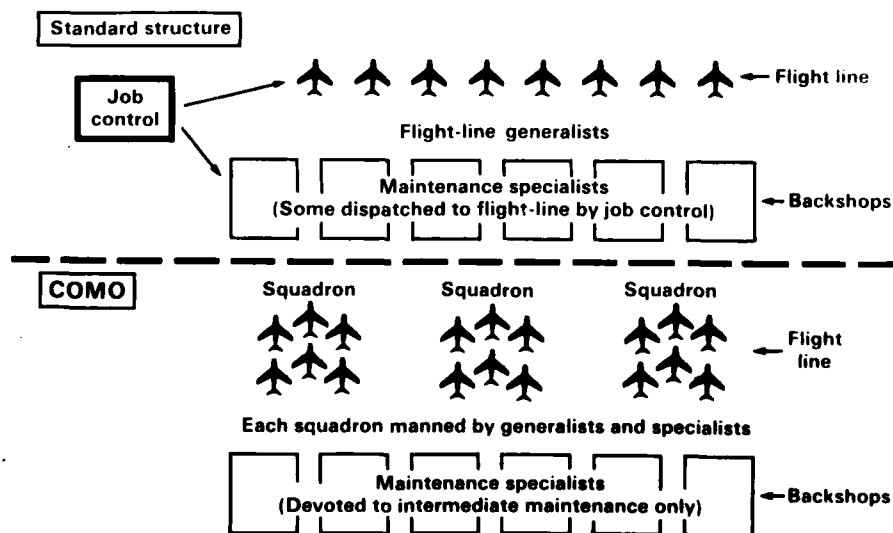


Fig. 3 - COMO compared with the standard maintenance structure

Several years ago, Rand evaluated three months of experience with COMO at a major European airbase operating F-4 Phantoms. It was found that COMO resulted in marked improvements in many measures related to aircraft launch and recovery. For example, there was a dramatic reduction (30 to 40 percent) in the time between an aircraft's landing and the commencement of work by the flight-line maintenance specialists. This reduction meant that fewer sorties were lost and fewer sorties occurred later than scheduled because of maintenance delays. Moreover, COMO allowed faster recoveries from conditions that grounded aircraft at that base. COMO is now the standard maintenance structure for the Tactical Air Forces. (These improvements are summarized in Fig. 4.) It illustrates how an organizational change within a base can have marked and measurable effects on the sortie generation capability of a force.[1]

INCREASED INTERDEPENDENCY AMONG BASES IN A THEATER: A RESPONSIVE INTRATHEATER LOGISTICS TRANSPORTATION SYSTEM

Several changes in the relationship among bases in a theater also could improve combat readiness.

Conventional wisdom holds that the combat commander at the lowest possible level ought to have all the resources within his command to perform his mission. This notion has led to the attempt to make each base largely self-sufficient. This goal is likely to become more and more difficult, perhaps impossible, to achieve. The uncertainties of

[1] COMO also has important ramifications for manpower, personnel, and training functions, but these are outside the bounds of this Note.

- 30-40% reduction in time from aircraft landing to start of work
- Fewer lost sorties charged to maintenance
 - 12% improvement in first sorties of the day
 - 45% improvement in turned sorties
- Fewer late sorties charged to maintenance
 - 50% improvement in first sorties of the day
 - 29% improvement in turned sorties
- Quicker recoveries from critical breaks
 - 25% more recoveries in less than 3 hours
 - 28% more recoveries in less than 6 hours

Fig. 4 — COMO's effect on aircraft launch and recovery measures

future wartime environments, variations in flying rates and repair capabilities across bases, and very grave vulnerability to airbase attack will make it virtually impractical to buy enough stock to guarantee base self-sufficiency.

It will be necessary to reallocate resources from base to base within a theater as the demands of the conflict dictate. Doing that will require an effective command and control system for support resource management, and an effective intratheater transportation system, sized, organized, and operated especially for the movement of critical support resources among bases. The current European intratheater transportation system is insufficient for that purpose. It

serves a variety of purposes, many of which are assigned higher priority than the movement of spare parts.

Using both the Dyna-METRIC and TSAR models described earlier, Rand has investigated the combat value of such a transportation system in the European theater. Figure 5 depicts the payoff--measured in number of flyable F-15 aircraft--of an intratheater transportation system devoted to the movement of F100 engines and modules between wartime F-15 bases: 44 additional flyable F-15s at the end of the first month of a conflict. This illustrates how a change in an important logistics function can improve the capability of the operational forces. Not incidentally, a change of this sort permits a host of other policy changes with the

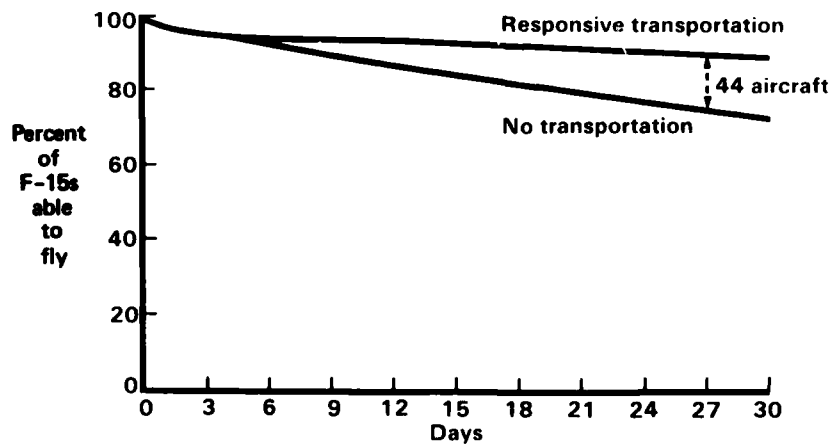


Fig. 5 — Combat value of a responsive intratheater transportation system: the case of the F-15 F100 engine

potential of enhancing combat readiness. Some of these are described below.

MORE EFFECTIVE USE OF LIMITED TEST EQUIPMENT RESOURCES: THE CASE OF THE F-15 AVIONICS INTERMEDIATE SHOP

An intratheater transportation system for the movement of spare parts would permit the selective consolidation of critical support resources within a theater. Such a procedure was found to be a promising response to the problem that surrounds the F-15 Avionics Intermediate Shop (AIS), the support facility that includes the test equipment for the F-15's avionics components. That problem has many dimensions. The first is a simple scarcity of resources: Unable to buy a sufficient number of Avionics Intermediate Shops, initial plans found the Air Force having to rely principally on individual sets of test equipment during wartime. For example, in 1980 eight of the nine bases projected to have AIS equipment in Europe during wartime were planned to have only a single set of test equipment. (Most of that equipment would be deployed to Europe from the United States.) Single sets are not likely to be up to the task of supporting wartime sortie rates because of (1) the rate at which avionics Line Replaceable Units (LRUs) are removed from the F-15, (2) the time it takes the AIS to test those removed components, and (3) the overall reliability of the AIS (and difficulty of stocking spare parts for it). Complicating the situation is the extreme vulnerability of the Avionics Intermediate Shop, which is housed in a large, unhardened building, to enemy attack.

Rand developed several alternative strategies for eliminating the projected sortie generation shortfalls; they are additional illustrations of how changes in support policies and resource levels can have a positive effect on combat readiness.[2] One alternative consisted of retaining the official AIS deployment plans and purchasing the additional test equipment and spare parts needed to achieve the wartime sortie goals. Two other alternatives involved different AIS deployment plans. One of those called for deployment of AIS to fewer European bases in wartime, permitting test equipment consolidation[3] and making hardening of AIS facilities more practicable. The other involved permanent consolidation of the AIS resources at two bases in the Continental United States and one hardened base in Europe.

Compared with the first alternative, the two strategies involving changes in AIS deployment plans offered reductions in AIS vulnerability as well as improvements in F-15 force flexibility and mobility. Those strategies would also be less costly.

CREATING "LEAN AND MEAN" OPERATING LOCATIONS: CENTRALIZED INTERMEDIATE LOGISTICS CONCEPT (CILC)

One of the strategies just mentioned involves the permanent consolidation of test equipment resources at a single location within the European theater. That notion is similar to the Centralized

[2] See J. R. Gebman et al., *Support for the F-15's Combat Avionics, Vol. 1: A Summary of Deficiencies and Policies for Improvement*, The Rand Corporation, R-2591/1-AF (forthcoming).

[3] Consolidation, i.e., colocated test stations, significantly increases test station availability because each station can be used to "troubleshoot" for the other and, in the event of a failure, each can be used as a source of spare parts.

Intermediate Logistics Concept (CILC) studied by the Air Force and Rand in the 1970s and later adopted by the Pacific Air Forces (PACAF).

The concept is easily described by comparing it with the "standard" logistics structure (see Fig. 6). Under the standard structure, the Air Force plans to operate during wartime out of Main Operating Bases (MOBs) and Colocated Operating Bases (COBs). [4] Each of those bases is designed to be essentially self-sufficient during wartime. In addition, once the major deployments are completed, the bases, although different in size, are essentially identical in operation and function: In terms of

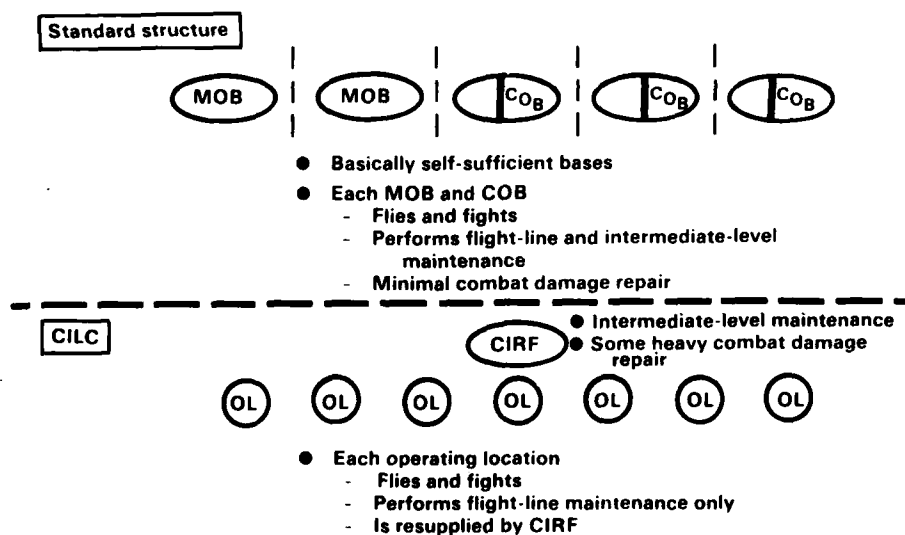


Fig. 6 - CILC compared with the standard support structure

[4] Colocated Operating Bases are main operating bases of allied air forces that will be shared by USAF units during wartime.

support tasks, each MOB and COB performs both flight-line and intermediate level maintenance.

The CILC calls for the consolidation of most theater intermediate level maintenance in one (or more) locations--typically rearward--within the theater. The other bases in the theater, called Operating Locations (OLs), look very different from MOBs and COBs. Each is relatively lean because it performs flight-line maintenance but little intermediate level maintenance, most of which is performed at the Centralized Intermediate Repair Facility (CIRF).

In principle, the CILC has many advantages related to improving wartime effectiveness. It reduces most of the important differences between peacetime and wartime operations and procedures, thereby making the transition from peace to war easier. Removing intermediate level maintenance responsibility from the operating locations increases the flexibility of the combat forces, allowing more effective dispersal, more intratheater mobility, and enhanced regroup capability. Locating and protecting the CIRF appropriately decreases the vulnerability of the theater intermediate level maintenance resources, although the usual vulnerabilities in the event of attacks on communications and transportation systems remain. (These latter vulnerabilities may be too difficult or even impossible to overcome in some regions of the world; in those cases dispersal may be a more effective means of increasing survivability. The Air Force has accordingly adopted CILC in the Pacific theater, but not in Europe.) Finally, there is reason to think that, where appropriate, such a structure can increase sortie production capability: The flight-lines at the operating locations are now singly

focused on sortie generation. Moreover, resource imbalances expected to occur in a dynamic and hostile environment can be attended to more effectively.

As an illustration of such a potential improvement in sortie production, Fig. 7 shows the effects of the loss of an airbase (but not its aircraft and crews) under both the standard structure and CILC. Loss of an operating location in the CILC structure does not entail the loss of any intermediate level maintenance capability. Under the standard structure, when an airbase is lost, a portion of the theater's intermediate level maintenance capability is lost as well, leading to a more rapid decline in the number of fully mission-capable aircraft in

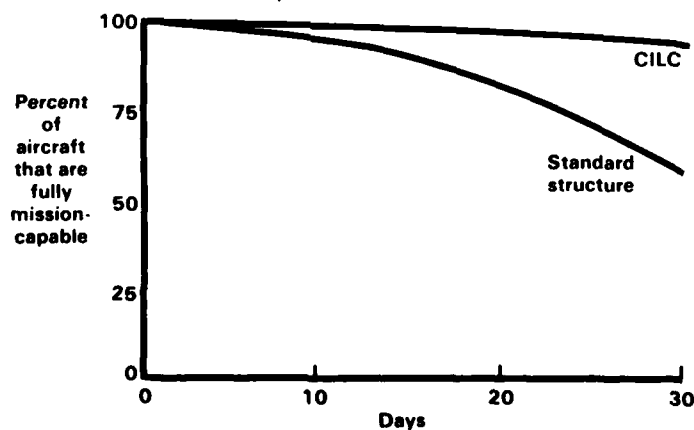


Fig. 7 - Performance after loss of a base:
CILC vs. standard structure

the theater, especially when resupply from the United States is not available.

Before leaving this subject, it is worth relating an unexpected result of an evaluation of the operation of CILC in PACAF. That evaluation turned up a number of improvements in measures normally associated with the characteristics of the hardware in use. For example, there were reductions (of about 25 percent) in both unscheduled removal rates and on-equipment fixes. The reasons are not known with certainty, but these reductions suggest that the effects of changes in support policies and organizations can be far-reaching. An obvious implication is that improved combat readiness does not always require increased hardware reliability or more plentiful supplies of resources.

III. ENSURING READINESS OF FUTURE WEAPON SYSTEMS

The preceding section illustrated a number of means of improving the readiness of currently fielded forces. Those means involved new support policies, organizations, and procedures. This section shifts attention to future weapon systems and the problems of ensuring their readiness.

Many new dimensions of expected future scenarios for the Tactical Air Forces create demanding goals for those forces, which in turn create distinct requirements for the hardware that those forces must operate. (See Fig. 2.) The growing enemy threat necessitates continued development of weapons with sophisticated countercapabilities, and the environments in which those weapons will have to operate necessitate fundamental changes in wartime support systems.

In order to allow rapid employment, redeployment, and dispersal, future fighter aircraft cannot require large amounts of support equipment and personnel for their mission-critical subsystems, such as avionics and engines. The removal rates for mission-critical components, usually among the most costly on the aircraft (a fact that makes large spare parts purchases impractical), must not be too high to permit the rapid generation of fully mission-effective sorties. Finally, in the case of combat avionics at least, there must be increased fault-isolation capability to be able to sustain critical subsystems in fully mission-effective states.

To understand where to direct efforts at improvement, consider the following example (Fig. 8). Suppose that to increase force response time, flexibility, mobility, and survival--goals necessitated by the projected constraints of future warfare--for the next tactical fighter, we eliminated the need for a deployed AIS by creating War Reserve Spares Kits (WRSKs) that contained all the necessary spare parts to support operations of the avionics suite for forty-five days. If that fighter contained avionics with removal rates equal to those of today's F-15, such a strategy would require \$1.3 billion,[1] almost three times the current investment in F-15 test equipment and avionics spare parts.

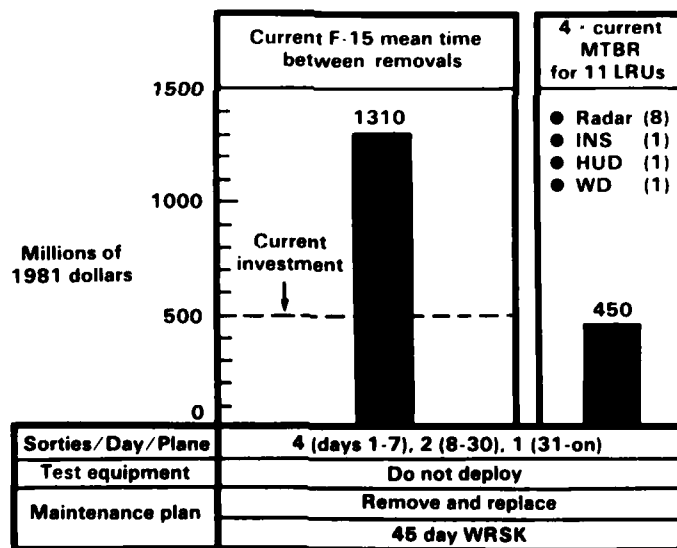


Fig. 8 - Avionics procurement costs for test equipment and spare LRUs (18 combat squadrons; excludes ECM)

[1] These estimates are expressed in 1981 dollars.

Such a step would probably not be affordable and would not surmount the fault-isolation problem described below. However, the problem takes on a different perspective when it is not driven by contemporary removal rates. For example, if on our next fighter aircraft we achieved a four-fold improvement in mean time between removals (MTBR) in just 11 LRUs, the total required investment in test equipment and spare parts would be only \$450 million.[2] It turns out that those 11 LRUs, which represent about 10 percent of the number of avionics LRUs on a modern tactical fighter, are also among the most important to combat mission success: They include the eight radar LRUs, the inertial navigation system (INS), the head-up display (HUD), and the weapons delivery (WD) computer. Achieving such an improvement in MTBR will require improvements not only in the reliability of the components but also, perhaps more important, in their fault-isolation characteristics.

Figure 9 illustrates one indication of the current fault-isolation problems: reoccurrent removals.[3] The chart is a history of removals from a single F-15 from the 49th Tactical Fighter Wing at Holloman Air Force Base for a three-month period in 1980. To use the radar as an illustration, note that the analog processor was removed and replaced on May 10 and again on June 2. On June 3 and again on June 4 the receiver was removed and was replaced. On June 5 the analog processor was again removed and replaced, and on June 10 the receiver was pulled. On June 22 the analog processor was removed and replaced once again. One way to

[2] RDT&E costs are excluded from both calculations.

[3] This term should not be confused with "recurrent removals," which the Air Force uses to describe removals that recur within three flights, or "repeat removals," used to describe those that repeat after the next flight.

		HUD	Navigation		Radar		S O R T I E S
Date	LRU	Processor	Inertial Measurement Unit	Attitude Reference Gyro	Receiver	Analog Processor	
May	1						22
	6						
	10						
June	2						29
	3						
	4						
	5						
	10						
	11						
	22						28
July							

(49% of 49th TFW planes had more removals per sortie than this plane)

Fig. 9 — Removals from plane 7133 (F-15)

interpret the sequence of events is that during the month of June the aircraft lacked a dependable radar, which is necessary for the F-15's unique combat responsibilities, even though the aircraft flew 29 sorties.

Similarly, in Fig. 10, the radar LRUs on another plane show the familiar pattern of reoccurring removals, but another phenomenon is also evident. Four LRUs were variously removed in attempts to fix a problem with the radar. When those actions were not successful, frustration set in, as evidenced by the June 11 removal and replacement of *all four* radar LRUs. Even that did not solve the problem; the pattern began to repeat itself shortly thereafter.

		Flight Control	INS	HUD	Radar				S O R T I E S
LRU Date		Computer	Inert. meas. unit	Display	Receiver	Target proc.	Data proc.	Analog proc.	
May	1								9
	15								
	20								
	23								
June	5								4
	8								
	11								
	27								
July	2								27
	15								
	16								
	20								
	21								

(16% Of 49th TFW planes had more removals per sortie than this plane)

Fig. 10 - Removals from plane 7109 (F-15)

Many people argue that the solution to such problems is to reduce the sophistication and complexity of our weapon systems. Those arguments are largely misguided. Many Air Force missions today *require* a high level of sophistication: The newer systems must perform more functions and perform them with greater precision than former ones did, and there must be more integration among functions. Although it is always useful to examine requirements statements to eliminate demands for unnecessary sophistication, for certain missions all levels of *effective* functional performance require sophisticated equipment. For example, the interception of low-flying, hard-to-detect, Soviet bombers and cruise missiles requires sophisticated radar, fire control, and

weapon capabilities. Achieving desirable reliability and fault-isolation capability in the sophisticated equipment required by missions of that type requires a special development process.

The fact that it has been done before makes us believe that changes in the development process can lead to improvements in removal rates of sophisticated avionics equipment. Two systems that have achieved excellent removal rates are the Minuteman I guidance system and the Carousel inertial navigation system (see Fig. 11). Both had very high removal rates after their initial development cycle, but underwent additional cycles to increase their availability by improving their reliability and fault-isolation characteristics. In each case, the

	Minuteman I guidance	Transport INS	F-15 INS
Development cycles	2	3	1
MTBR (hr) after 1st cycle	600	100	75
2d cycle	9000	500 - 600	—
3d cycle	—	1500	—

Fig. 11 — Comparison of inertial system developments

improvement was fifteen-fold. By comparison, the F-15 inertial navigation system, which operates in a much more demanding environment and in many more modes, has undergone only a single cycle of development. Its MTBR is short and has not improved over time.

The key, we believe, is to make more than one pass through the development cycle. This is necessary because a developer cannot use engineering or reliability theory to predict adequately where and how often failures will occur. One development cycle, including realistic operational testing, is needed to identify significant failure modes. A further cycle is required to reduce failure rates to acceptable levels and to develop an adequate fault-isolation capability.

We call such a strategy *maturational development*. [4] Although it is time-consuming and costly, it need not delay the introduction of new weapon systems into the inventory. If the development of critical subsystems were allowed to begin before (instead of after) the development program for the weapon platform, multiple development cycles could be completed in time for incorporation of the mature subsystem in the full weapon system. Because of the investment in time and money required for maturational development, the resulting hardware ought to have application across a number of weapon systems. The existence of mature building blocks that were widely applicable would thus permit the introduction of modular functional performance improvements.

As demonstrated many times, the problems of subsystem integration at the full weapon system level require a similar approach. It is

[4] For details, see J. R. Gebman et al., *The Need for a Maturational Phase During Avionics Development*, The Rand Corporation (forthcoming).

evident, however, that this too would require significant changes in the way that most weapon system programs are managed. To illustrate, Fig. 12 shows the testing and production schedules for five fighter aircraft developed by the United States Air Force under varying acquisition philosophies in the 1960s and 1970s. The dots on the test program bars indicate when a high-rate production decision was made (the equivalent of DSARC IIIB). In each of the five programs, that decision was made well in advance of the end of testing (and often before the onset of the operational test and evaluation phase). Note as well that by the time testing was concluded in each program, with a period for adequate feedback of the results assumed, a substantial number of aircraft had

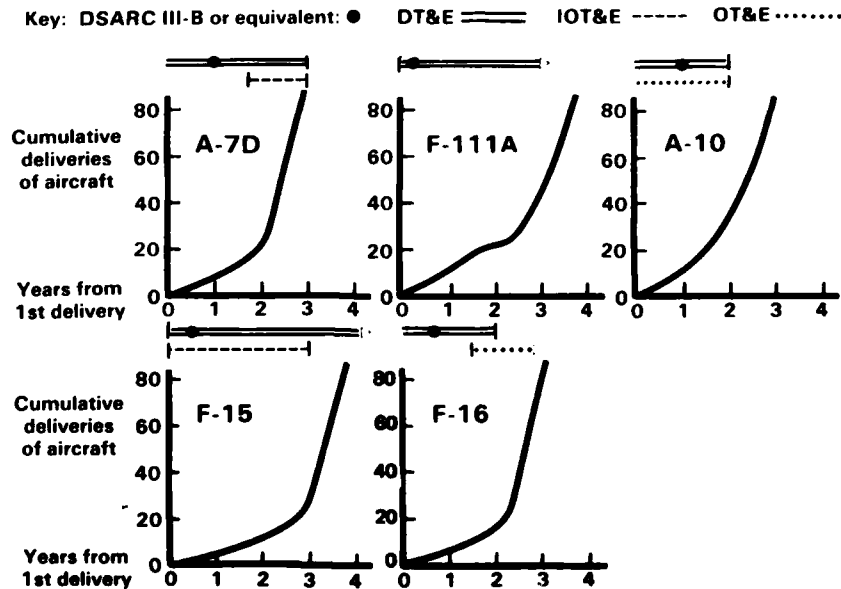


Fig. 12 - Testing and production schedules of five recent tactical aircraft programs

already been delivered into the field. In almost every case, substantial deficiencies were identified late in the test program or in early operational use that degraded the operational effectiveness of the aircraft. In those cases, however, so many aircraft had been delivered to the field that the Air Force chose to accept the degraded performance rather than incur the great expense of retrofitting the required changes.

What is needed is a new way of managing the transition from development to production at the major system level that will ensure the prompt identification, feedback, and correction of problems. Such an approach requires the sensible use of prototypes during both advanced and full-scale development, and strong incentives to exploit available mature building blocks. Under such a strategy, there would be no delay in beginning production, but production would continue at a low rate until intensive and realistic operational testing could be accomplished and used in the design process. Only then would a system go into full production. We believe that such an approach, especially when combined with maturational development of critical subsystems, will yield weapon systems with vastly improved operational capabilities.

IV. SUMMARY

This Note has described an approach for identifying and meeting the need to improve combat readiness. That approach rests on three basic ideas. First, readiness can be assessed only within the context of explicit wartime scenarios, a requirement that renders most popular characterizations of readiness inappropriate and misleading. Second, readiness is the product of many factors, including the weapon system's characteristics, the expected stocks of support resources in wartime, and the performance of support systems. Third, sophisticated equipment is not inconsistent with the goal of high levels of readiness, even in the face of increasingly demanding and stressful combat environments. Achieving that goal, however, will require new, effective support policies, and will require major changes in the customary subsystem and full-system acquisition processes.

